



Pilot Scale Test Of Compact (Short Retention Time) Passive Treatment Process for Acid Mine Drainage Using Agri-Waste in Japan

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Abstract

A biological passive mine water treatment system, which is environment-friendly and energy saving, has been developed by JOGMEC (Japan Oil, Gas and Metals National Corporation). In this “JOGMEC process”, contaminated mine water is treated in a vertical-flow anaerobic bioreactor that utilizes sulfate reducing bacteria (SRB). It is necessary to introduce compact passive treatment system with a higher flow rate (shorter hydraulic retention time (HRT)).

Keywords: AMD, Passive Treatment, Sulfate Reducing Bacteria

Introduction

Japan Oil, Gas and Metals National Corporation (JOGMEC) has been conducting survey research on passive treatment since 2007 and has focused on treatment methods to remove metals contained in acid mine drainage as sulfide by utilizing of sulfate reducing bacteria (SRB).

Field tests have been conducted with anaerobic reactors filled with “rice bran” in addition to “rice husk” for acid mine drainage since 2014. Continuous removal of metals for more than 300 days has been confirmed with the hydraulic retention time (HRT) of 50 hours under the conditions close to natural environment that the temperature in the winter drops to around -10 degrees. Besides, continuous removal for more than one year has been confirmed with the HRT of 25 hours.

As described above, IT has been confirmed that AMD can be treated for a long period under 12.5 HRT to 50 HRT conditions by “JOGMEC process” which removes metals as sulfide using an anaerobic reactor filled with agricultural waste such as rice husk and rice bran. Then, since November 2016, the pilot scale demonstration test for AMD containing iron, zinc, copper, and cadmium was started.

Methods

1) Summary of equipment of pilot scale test

The pilot scale test equipment was installed at abandoned mine site. “Iron oxidation and removal reactor” which oxidizes and precipitates iron ions in AMD utilizing the function of iron oxidizing bacteria and “Anaerobic reactor” which precipitates various metals as sulfide utilizing the function of SRB was installed. The appearance and treatment flow of this test facility are shown in Fig.1.

2) Structure and Contents of reactor

Iron oxidation and removal reactor

The iron oxidation reactor is made of PVC and its dimensions are W 1.6 m × D 1.3 m × H 1.0 m. Since the iron oxidation reactor utilizes the function of iron oxidizing bacteria which is aerobic bacteria, it is structured to raise the dissolved oxygen concentration by introducing raw water into the reactor like a shower. The iron oxidation reactor was filled with rice husk as carrier of iron oxidizing bacteria and capturing material of precipitated iron hydroxide. Rice husk was filled to a thickness of about 0.5 m, a volume of about 1 m³.



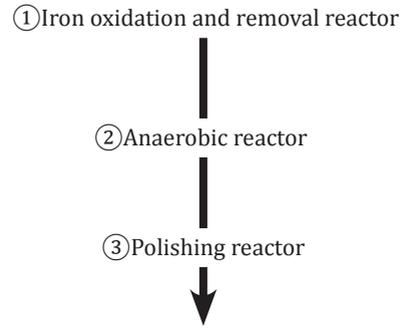
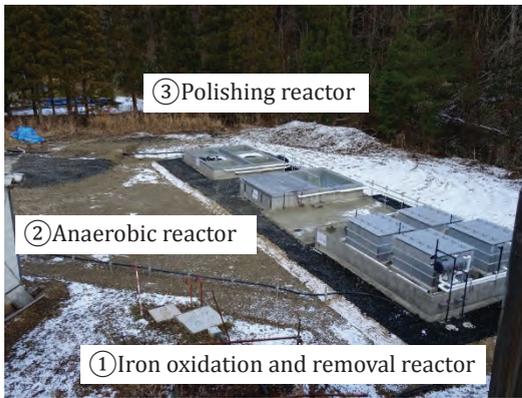


Figure 1 Summary of pilot scale test's equipment

Anaerobic reactor

In the anaerobic reactor, sulfate ion is reduced by SRB and metal ions contained in AMD are precipitated mainly as sulfide. The reactor is made of concrete and its dimensions are W 3 m × D 2 m × H 2.5 m. The reactor is buried in the semi-underground, 1.8 m out of 2.5 m in height is installed in the ground.

As the contents, at the bottom of the reactor, limestone (ϕ 20 mm to 40 mm) was filled to a thickness of about 0.15 m to prevent clogging of the perforated drain pipe, and whole of reactor, rice husk for substrate, limestone for pH buffering and soil for resource of bacteria were mixed and filled to a thickness of 1 m. Each weight is 600 kg of rice husk, 2400 kg of limestone (ϕ 20 mm to 40 mm), 60 kg of soil. Furthermore, rice bran as organic matter was filled in the upper layer. In order to ensure permeability inside the reactor, rice bran was divided into mesh bags and filled in consideration of maintainability such as additional filling and removing. The anaerobic reactor was set at 4 ports in the depth direction (1st port: 0.25 m from the top of the rice husk layer, 0.5 m at the 2nd port, 0.75 m at the 3rd, 4th port: 1.0 m) can be sampled.

3) Condition of Experiments

Quality of Raw Water

Table 1 shows the quality of the raw water to be treated in this test.

Analysis of items

The raw water to be treated and the water after treatment were periodically sampled and analyzed. Items for testing were temperature, pH, Oxidation-Reduction Potential (ORP), metal concentrations (such as iron, copper, zinc, and cadmium), sulfate ion concentration, sulfide ion concentration (hydrogen sulfide, hydrogen sulfide ion, and other sulfide ion were fixed as sulfide ion in strong alkaline condition, and analyzed with a spectrophotometric method using methylene blue), and chemical oxygen demand (COD).

Water Flow rate

The treated raw water was passed through the iron oxidation and removal reactor at a flow rate of about 5.2 L/min, the HRT is 2.5 hours. About anaerobic reactor, at a flow rate of about 2.6 L/min. and the HRT in the anaerobic reactor is 25 hours.

Results

1) Performance of iron oxidation and removal reactor

Fig.2 shows iron concentration of treated water divided into ferrous and ferric iron. For about 5 months from the start of the test, the ferrous concentration of treated water was low but the ferric iron concentration was slightly high and the total iron concentration

Table 1. Average Quality of Treated Water (Unit : mg/L)

	pH	T-Fe	Zn	Cu	Cd	SO ₄ ²⁻
Drainage	3.5	38	15.4	4.9	0.06	310



was slightly less than 10 mg / L. After April, the ferric iron concentration was decreasing and the total iron concentration gradually decreased, dropping to less than 4 mg / L. Thereafter, although the ferric iron concentration increased in winter, the ferrous iron concentration remained at a low value, the total iron concentration has been remained at only 8 mg / L at a high level, stably lower than 10 mg / L.

2) *Performance of anaerobic reactor*

Fig.3 shows the transition of each depth of the anaerobic reactor and pH of treated water, and Fig.4 shows the transition of ORP. According to Fig. 3, the pH is below 5 at the 1st port of the anaerobic reactor (25 cm deep from the top of the rice husk layer), and it exceeds 6 at the second and subsequent ports. It has thought that the pH has been rising inside the anaerobic reactor by limestone mixed in the rice husk. According to Fig. 4, the ORP in the anaerobic reactor was positive

in 1 month from the start of water flow in the first port, also shows an upward trend in the second and subsequent ports, after 2 months the ORP in the third port was a positive value. Fig.5 shows the transition of sulfate ion concentration of raw water and treated water of anaerobic reactor. According to Fig. 5, it is found that the sulfate ion concentration in the treated water decreased by about 100 mg / L or more in the anaerobic reactor immediately at the initial period of the test. As the test progresses, the sulfate ion concentration of the treated water showed an upward trend.

Fig. 6 shows the transition of the total zinc concentration in the treated water of the anaerobic reactor and the zinc ion concentration in filtered with the 0.45 μm syringe filter.

According to Fig. 6, the zinc ion concentration of the treated water in the anaerobic reactor is very low, and zinc ions contained in the treated raw water of about 15 to 18 mg / L are removed inside the anaero-

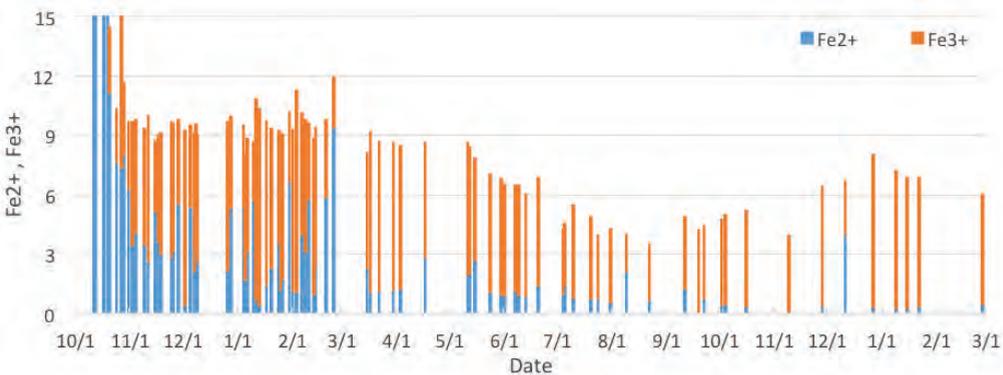


Figure 2 Changes of iron concentration of treated water

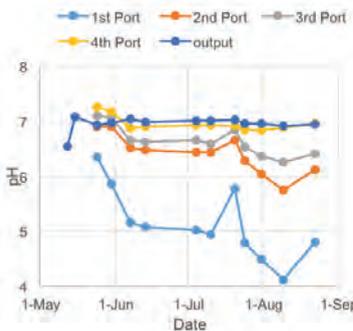


Fig.3 Changes of pH

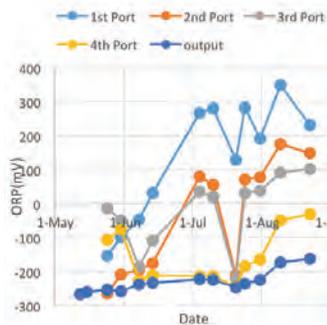


Fig.4 Changes of ORP



bic reactor. However, it can be confirmed that the total zinc concentration in treated water tends to rise gradually. It is presumed that sulfate ion reduction by SRB occurs in the anaerobic reactor, and metal ions contained in raw water have been precipitated mainly as sulfide in the anaerobic reactor. However, since the total zinc concentration in the treated water is high and the zinc ion concentration is low, suspended particles such as sulfide of zinc precipitated have not been captured in the anaerobic reactor and flow out of the system.

Discussion

In the anaerobic reactor, it is strongly suggested that sulfate ion reduction by SRB occurs and metal ions precipitate mainly as sulfide. However, it is also confirmed that a phenomenon in which suspended metal flows out into treated water has occurred. In the anaerobic

reactor, reduction of sulfate ion by SRB occurred, metal ions precipitated as sulfide, and it was assumed that the sulfide was trapped by filled rice husk, but as shown in Fig.6, it is conceivable that the suspended particles are not trapped sufficiently.

According to Fig.4, from the beginning of July, ORP of the 1st to 3rd ports of the anaerobic reactor shows positive value, indicating that it is an oxidizing condition. Generally, when SRB is activated, ORP would be indicated about -200 to -400 mV.

In this test, it is considered that SRB is not activated at the first to third ports of the anaerobic reactor, and it is considered that the SRB is activated in the third to fourth ports.

Thus, it is considered that the sulfate ion reduction of SRB is occurring in the limited area of the anaerobic reactor, and there might be a possibility that the area where precipitated sulfide particles are captured is not sufficient.

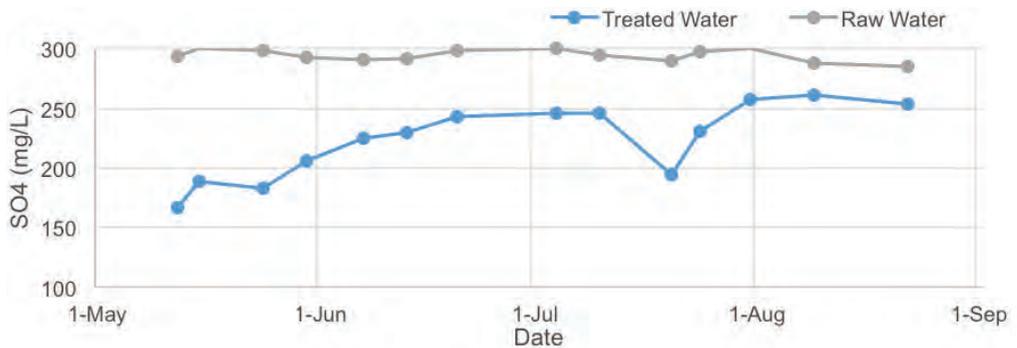


Figure 5 Changes of sulfate ion concentration of raw water and treated water

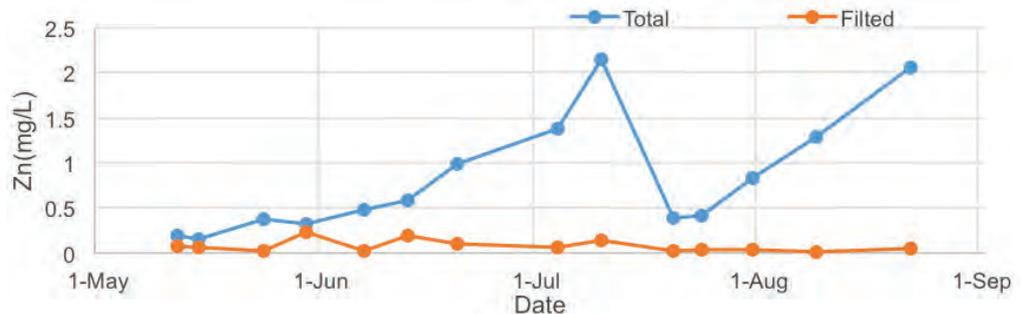


Figure 6 Changes of zinc concentration of raw water and treated water



In order to trap the precipitated sulfide particles in anaerobic reactor, it is estimated that it is important to supply low molecular organic matter with high palatability of SRB at a sufficient concentration so that SRB tends to be activated.

It may be considered to increase the layer thickness of the anaerobic reactor to enlarge the area for capturing precipitated particles. As a result, with regard to the construction of the reaction tank, it is possible to make use of the depth and possibly make the facility area more compact.

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